

QURILISH, EKSPLOATASIYA VA TRANSPORT TIZIMLARI HISOBINING USHLUBLARI

УДК (UDC) 624.193.3

CONSTRUCTION FEATURES OF TRANSPORT TUNNELS IN THE MOUNTAIN AREAS OF UZBEKISTAN

Миралимов М.Х.¹, Нормуродов Ш.У.²
M.X. Miralimov¹, Sh.U. Normurodov²

¹ – Ташкентский институт проектирования, строительства и эксплуатации автомобильных дорог (Ташкент, Узбекистан)

² – Ташкентский институт инженеров железнодорожного транспорта (Ташкент, Узбекистан)

¹ – Construction and Maintenance of Automotive Roads (Tashkent, Uzbekistan)

² – Tashkent Institute of Railway Engineers (Tashkent, Uzbekistan)

Abstract: The paper provides information about the transport tunnel 19,2 km long which was recently completed on new electrified railway line “Angren-Pap” in the mountain area of Uzbekistan. It is noted that the most actual for transport tunnels is account of seismic activity of geological environment in the process of design, construction and maintenance. There are given the effects of earthquakes on underground structures and regularities of displacement and stress distribution in the tunnel linings under seismic impacts. The accumulated experience of earthquake-resistant construction in Uzbekistan shows the need to consider several design schemes for the interaction of tunnels in the rock mass at a sufficient depth,, cases of crossing the tectonic zones by the tunnel.

Key words: construction, mountain area, transport tunnels, portal, emergency tunnel, main tunnel

ОСОБЕННОСТИ СТРОИТЕЛЬСТВА ТРАНСПОРТНЫХ ТОННЕЛЕЙ В ГОРНЫХ РАЙОНАХ УЗБЕКИСТАНА

Аннотация: В статье представлена информация о транспортном тоннеле длиной 19,2 км, который недавно был завершен на новой электрифицированной железнодорожной линии «Ангрен-Пап» в горной местности Узбекистана. Отмечено, что наиболее актуальным для транспортных тоннелей является учет сейсмической активности геологической среды в процессе их проектирования, строительства и эксплуатации. Приведены данные о влиянии землетрясений на подземные сооружения и закономерности смещения и распределения напряжений в обделках тоннеля при сейсмических воздействиях. Накопленный опыт сейсмостойкого строительства в Узбекистане показал необходимость рассмотрения нескольких схем проектирования тоннелей с учетом взаимодействия с массивом горных пород на достаточной глубине, а также случаи пересечения тоннелей тектонических зон.

Ключевые слова: строительство, горная местность, транспортные тоннели, портал, аварийный тоннель, главный тоннель

1. INTRODUCTION

The development of transport sector of economy is particular importance for Uzbekistan due to its vast territory and uneven distribution of resources. From the first days of independence, the country's leadership pays great attention to the phased connection of railway of all regions with center of the country and creation of a single independent transport system of the Republic. The new “Angren

– Pap” electrified railway line which built in Uzbekistan with a length of more than 130 km contains the longest railway tunnel in Central Asia with a length of 19.2 km. In the world ranking in terms of complexity it takes 8th place among tunnels located in mountainous areas, and 13th in tunnel length.



Figure 1. Location of tunnel in the international railway route

The tunnel is intended for railway communication between metropolitan area of Uzbekistan and Ferghana Valley, its route crosses mountain ranges that are very complex in geological and tectonic terms at an altitude of more than 1300 m above sea level. The commissioning of the railway line increases the transit value of Uzbekistan, and in the future it can become a key element of the most important international transport corridors, part of one of the projects of “Silk Road Economic Belt” (Figure 1). The implementation a set of works on design and construction of tunnel on a competitive basis was carried out by the company “China Railway Tunnel Group”.

2. CONCEPT OF “ANGREN-PAP” RAILWAY TUNNEL PROJECT

2.1. Geological structure

Uzbekistan is a country located in the middle of midsection of Central Asia with an elevated territory in the East, and a low territory in the West. The area of tunnel crosses the Kuraminsky range, which is the southwestern spur of Chatkal mountains and is catchment of the northwestern river - the eastern slope of the Ferghana Valley. The geological structure of area was mainly formed during the Hercynian orogenesis, which was subsequently exposed to Alpine orogenesis. In the course of geological formation movement, huge anticlines and strong movements arose and similar anticlines formed very complex folds and large fault zones in a northwest direction. Fault zones and magmatic inclusions are very complex and sometimes cover structural folds that were formed during the Hercynian orogenesis [1,3].

In the area of the tunnel construction fault structures are developed, mainly of the north-west and south-east direction, which are actively affected by earthquakes. In total, 17 faults were identified, including 8 faults that cross tunnel or have a significant impact on tunnel with their dislocations (Figure 2, Figure 3).



Figure 2. Dislocated and weathered fault zone



Figure 3. Dislocated fault zone, interbedded by lens

The layers in tunnel area is mainly formed by Holocene of the Quaternary, the thin plutonic rock of triassic system, interbedded of volcanic rock, nodiorites, orthofirs, syenites, granosyenites, quartz porphyries, granite porphyries, andesites and quartz andesites. The hardness and integrity of the surrounding rocks varies with the depth of various sections.

2.2. Route scheme and tunnel characteristics

At the stage of preliminary survey work researchers from Uzbekistan performed a significant volume of research and the necessary choice of a route scheme and built the foundation of a key section outside the tunnel. The western portal of tunnel is located in the gorge (mileage of western portal - MK39 + 155) about 3 km from A373 highway; the eastern portal of tunnel is adjacent to the existing rural highway (the mileage at the eastern portal is MK58 + 355) and the total length of the tunnel is 19,200 m.

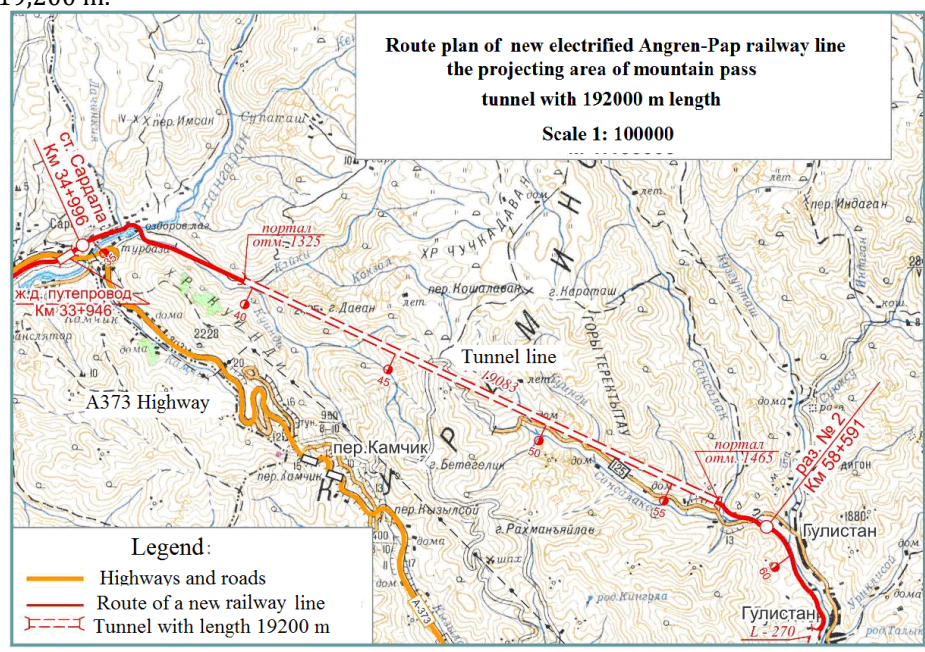


Figure 4. The layout of tunnel route

The entrance to the tunnel is located in the valley, where almost 5-km mountain road serves as a necessary passage from A373 highway to the entrance of tunnel. The current mountain road has an approximate width of 3-5 m, in some sections its width is less than 3 m. In order to reduce rocks excavation and to prevent avalanches and rockfall during operation the entrance to the tunnel can be provided by subsurface excavation at the elevation MK39+170 and tamped 15 meters of section which open-cutted outside of tunnel; in this case, the portal's mileage would be at MK39+155. It is proposed to use a portal with an input tip. The exit from the tunnel is in an adjacent position with the mountain road. The existing road is at a lower level but it is in good condition. The mountain road leads directly to the A373 highway, where traffic is relatively convenient. The portal is located on a steep slope with a deep ravine outside of tunnel and tunnel will be connected to large overpass (Figure 5).



Figure 5. Relief for portals on entry and exit parts of main tunnel

According to the requirements of the standard “Tunnels of Rail and Automotive Roads (КМК 2.05.05-96)”, tunnels exceeding 100 m in length must be close constructed with an emergency tunnel. So preliminary surveys of this project was set position of portals of emergency tunnels (Figure 6, Figure 7). Also these investigations showed the distance between emergency and main tunnels should contain at least 29 m.

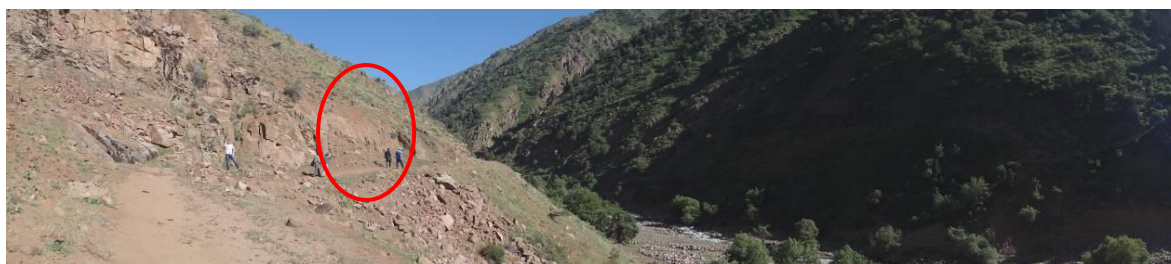


Figure 6. Relief of entrance to emergency tunnel



Figure 7. Relief of exit from emergency tunnel

The tunnel is developed at five working faces including entrance, exit and three inclined shafts. In accordance with scheme of inclined shaft (mine face) the main tunnel between inclined shaft №1 and №2 will be key section for controlling construction time. For construction work in the direction of entrance and exit parts after mine work into main tunnel, respectively, four working mine faces were installed in inclined shafts №1 and №3 (Figure 8).

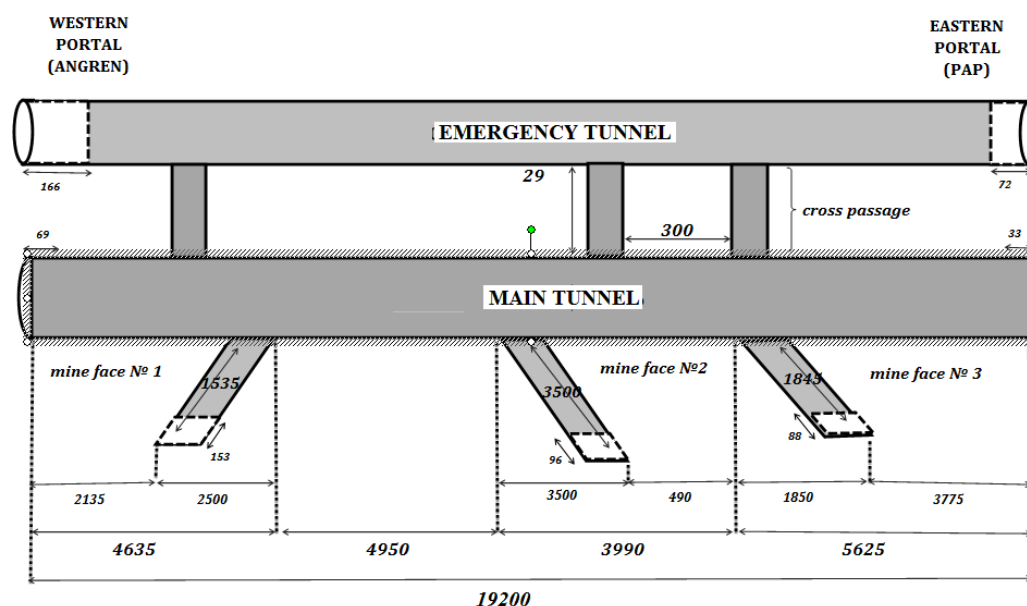


Figure 8. The layout of tunnels (unit, m)

The main and emergency tunnels are interconnected by 64 connecting cross passages (Figure 8). A bunker was organized for excavated material as a transshipment site for rail and railless vehicles. The organization of construction work according to the above scheme allowed reducing the total period of construction term to approximately 36 months, and completion time in the arch parts of main tunnel was 34 months, including one month of construction preparation in each working face and 2 months of the entire period for installation of equipment. Depending on the engineering and geological conditions construction work in main tunnel is organized by step face or solid section using blasting holes. The length of holes is taken up to 4.0 m, diameter 40–42 mm. For blasting cartridge explosives 32–36 mm in diameter are used. If necessary reverse arch is additionally constructed in the portal section, in the shallow section of tunnel arch and in impact areas of fault zones. In areas with complicated conditions is applied principle "Arch excavation and preservation of earth core " (Figure 9). Depending on geological conditions surrounding rocks are hardened using surface cementing and anchor bolts, preliminary cementing of the bases. Advance supporting measures are also used, such as using long pipes with length of 10-40 m.



Figure 9. The view of entrances of main and emergency tunnels

The cross section of tunnel is determined depending on operating conditions (design speed 63-90 km/h, one tunnel, one track), type of surrounding rocks, engineering geological and hydrogeological conditions, depth of tunnel, structural pressure characteristics, combination of construction conditions and conditions environment, structural calculations and complex analysis. The cross section of tunnel is main parameter, which is adopted as a permanent structure, designed to achieve the required

strength, stability and durability. The completed tunnel must be adapted to operational needs and maintenance. The main tunnel uses the combined lining. The lining structure consists of primary and secondary lining. The combined lining was used in the portal section of the emergency tunnel, in areas with developed fracturing, with abundant groundwater and other adverse geological conditions in areas where strengthening is required. Anchor bolts and shotcreting are applied for permanent strengthening on sites where good stability of surrounding rocks and lack of underground waters are noted. The concrete reinforced with steel fibers with the content of 1% is applied in high-altitude areas with lateral pressure and areas with possible bouncing. In areas with an average likelihood of firing, anchor bolts are also used to mount the mountains[2].

Advanced technology and the organization of drilling and blasting operations, used machinery and equipment made it possible to achieve high work efficiency, so the utilization rate of holes reaches 95%. Permanent monolithic concrete lining for the tunnel is being constructed using mechanized mobile formwork (Figure 10).



Figure 10. The mechanized mobile tunnel formwork

3. USING EXISTING EXPERIENCE IN ASSESSING EARTHQUAKE RESISTANCE OF TUNNEL LINING

The uniqueness of new electrified “Angren – Pap” railway line is determined by a complex of complicated geotechnical factors and high seismicity of territories (8-10 points on the MSK scale). These facts illustrate dependence of earthquake resistance of underground structures on geological structure of the surrounding bulk of reservoir rock, the confinement of destruction of the working mine to interfaces areas of heterogeneous rocks. A correct assessment of earthquakes effects reveals typical damage on structures, their interaction with ground at oscillating, determine relative seismic resistance and weak places in the lining with various soils, account the quality of construction, develop recommendations and anti-seismic measures.

The accumulated experience of earthquake-resistant construction in Uzbekistan shows the need to consider several design schemes for interaction of tunnels in the rock mass at a sufficient depth, cases of tunnel crossing of tectonic zones, as well as sections adjacent to portal parts. Factors affecting on destruction are diverse. The strength of structural elements or linings depends not only on materials manufactured, but also on the physicomechanical properties of the surrounding massif. Nevertheless, one can notice two characteristic points. Deep underground structures are destroyed due to dynamic stresses exceeding the tensile strength of strengthening materials.

The analysis of existing proposals and recommendations for design of linings for underground structures in seismically active areas shows that existing calculation methods based on the interaction of linings with massif under action of long horizontally directed compression wave make it possible to take into account the variety of effects that structure can undergo during an earthquake. The calculation accounts the effect of seismic shear waves, various possible directions of wave propagation regarding structure, alternating loads, tangential stresses at the contact of the lining with the rock and a significant dependence of the load distribution on the shape of the cross-section of the lining. Such

assessment based on the forming diagrams of normal tangential stresses in the lining allows obtaining forces corresponding to maximum possible compressive and tensile stresses[3,4].

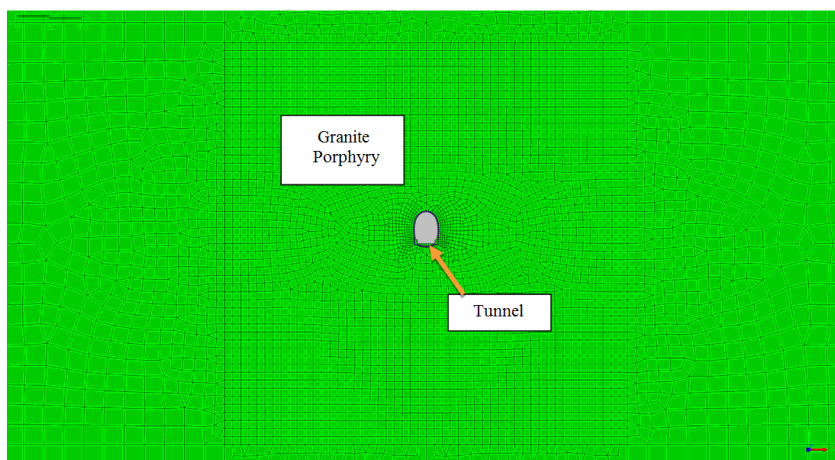


Figure 11. General view of finite element model

The following relationships are proposed for calculating seismic forces[4,5]:

1. Inertial loads from mass of lining elements are considered as applied in the center of gravity of the elements or as distributed along the element in the vertical and horizontal direction.

2. For deep tunnels inertial load of soil mass in vertical and horizontal directions is calculated as:

$$P_r^B = AK_1 \gamma \frac{B}{2f}, \quad P_r^T = (P_r^B + AK_1 \gamma \frac{h}{2}) \tan^2(45^\circ - \frac{\varphi}{2}) \quad (1)$$

$$P_r^B = AK_1 \sum_{i=1}^n \gamma h_i, \quad P_r^T = P_r^B \tan^2(45^\circ - \frac{\varphi}{2}) \quad (2)$$

where AK_1 is the factor of seismicity, A is the conditional seismic acceleration of rock particles in fractions of acceleration of gravity, it takes the value as 0.1, 0.2, 0.4, respectively, for the calculated seismicity of 7, 8, 9 points; $K_1=0.25$ is factor considering permissible damage tunnel lining.

At the same time, these are accepted: $A=0.4$, $K_1=0.25$, $V_p=1420$ м/сек, $V_s=870$ м/с, $T_0=0.5$ s, $\gamma=0.0275$ MN/м³, $\lambda=0.47$, $P_r^B=311$ kN/м², $P_r^T=0.146$ kN/м², $P_{r,xy}^B=190$ kN/м², $P_{r,xy}^T=89.5$ kN/м².

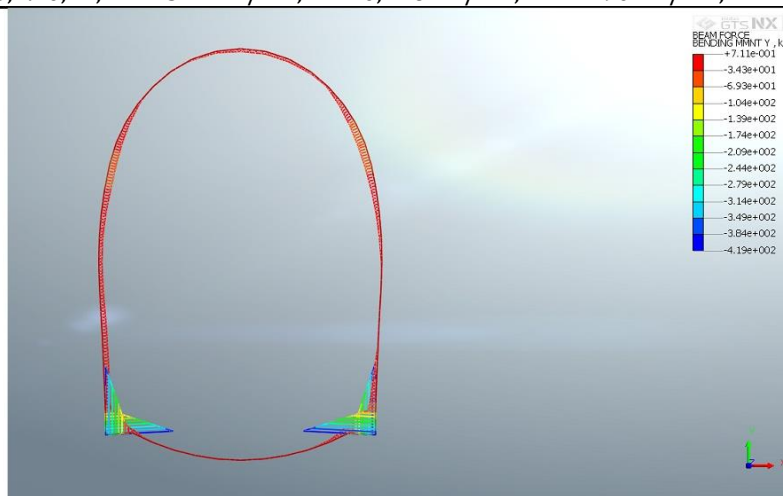


Figure 12. Bending moment diagram (min)

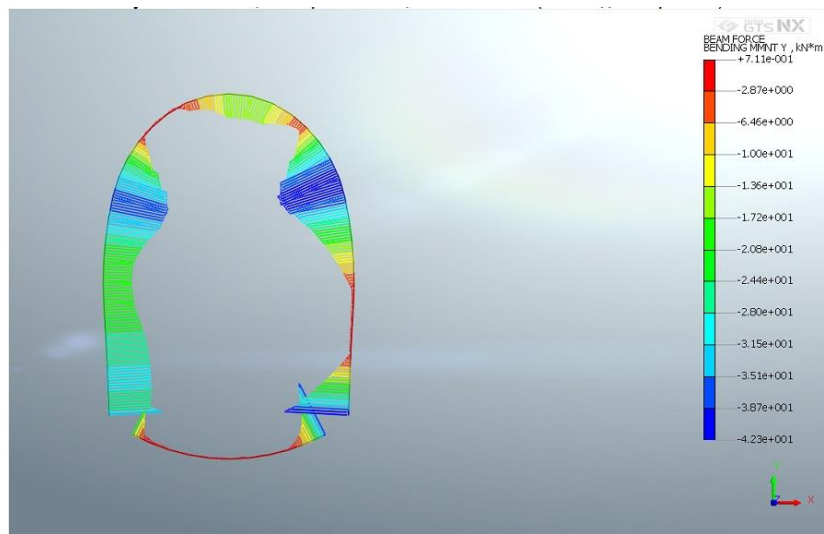


Figure 13. Bending moment diagram (max)

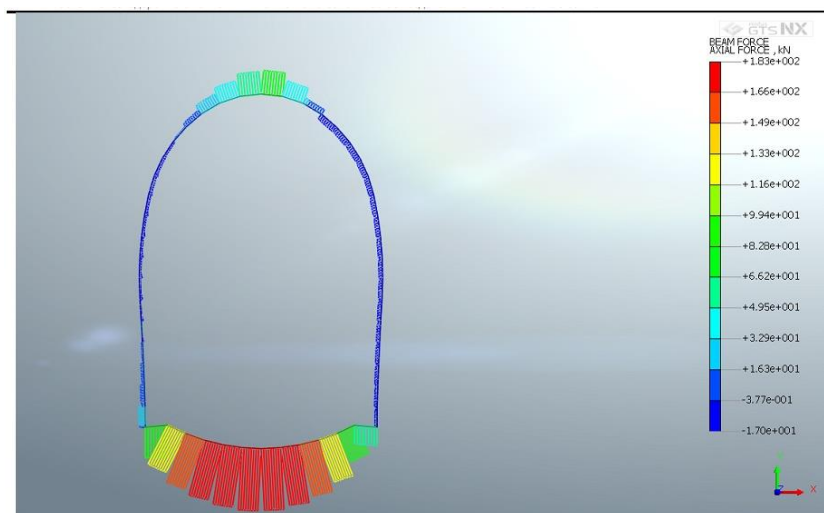


Figure 14. Diagram of longitudinal tensile forces

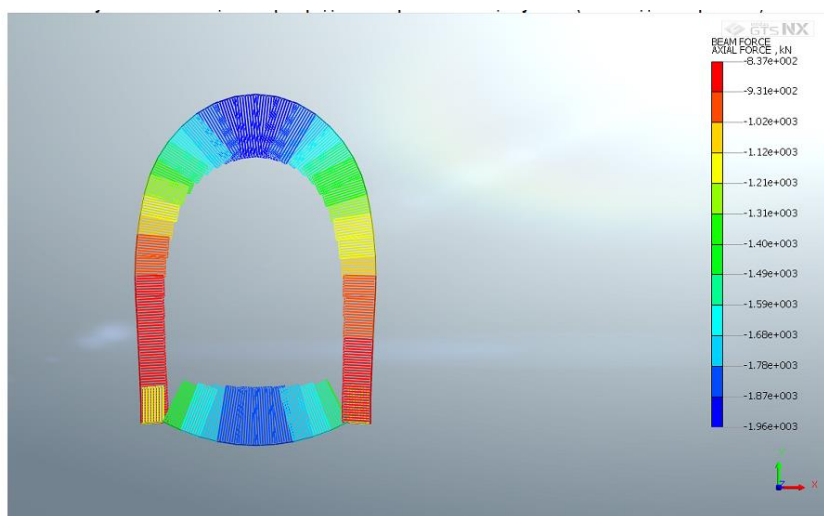


Figure 15. Diagram of longitudinal compressive forces

Based on results of numerical dynamic calculations with finite element modeling (Figure 11) values of bending moments and longitudinal forces are obtained in the tunnel lining with account three options for location of epicenter of the earthquake (Figure 12, Figure 13, Figure 14, Figure 15). There was found that seismic stresses make up no more than 30-35% of the stresses arising under static loads.

These calculation results should be taken into account with larger variation of earthquake epicenter, i.e. tunnel reinforcement should be performed at maximum moments and longitudinal forces with accounting symmetry of possible seismic effect[5].

The recommended maximum calculated values of internal forces for designing railway tunnel lining are following:

The compressive force - 240 t; The tensile force - 35 t; The bending moment (symmetrically) - 15 t m (in the zone of junction walls with tray of tunnel - 50 t•m); The maximum shearforce is 10 t (in the zone of junction walls with tray of tunnel - 110 t).

4. CONCLUSION

In the current work is presented construction features of new transport tunnel In the mountain area of Republic of Uzbekistan. . The geological structure of area was mainly formed during the Hercynian orogenesis, which was subsequently exposed to Alpine orogenesis. In the course of geological formation movement, huge anticlines and strong movements arose and similar anticlines formed very complex folds and large fault zones in a northwest direction. Fault zones and magmatic inclusions are very complex and sometimes cover structural folds that were formed during the Hercynian orogenesis. The western portal of tunnel is located in the gorge (mileage of western portal - MK39 + 155) about 3 km from A373 highway; the eastern portal of tunnel is adjacent to the existing rural highway (the mileage at the eastern portal is MK58 + 355) and the total length of the tunnel is 19,200 m. The organization of construction work according to developed scheme allowed reducing the total period of construction term to approximately 36 months, and completion time in the arch parts of main tunnel was 34 months, including one month of construction preparation in each working face and 2 months of the entire period for installation of equipment. The cross section of tunnel is determined depending on operating conditions (design speed 63-90 km/h, one tunnel, one track), type of surrounding rocks, engineering geological and hydrogeological conditions, depth of tunnel, structural pressure characteristics, combination of construction conditions and conditions environment, structural calculations and complex analysis. The accumulated experience of earthquake-resistant construction in Uzbekistan shows the need to consider several design schemes for interaction of tunnels in the rock mass at a sufficient depth, cases of tunnel crossing of tectonic zones, as well as sections adjacent to portal parts. Factors affecting on destruction are diverse. The analysis of existing proposals and recommendations for design of linings for underground structures in seismically active areas shows that existing calculation methods based on the interaction of linings with massif under action of long horizontally directed compression wave make it possible to take into account the variety of effects that structure can undergo during an earthquake. Based on results of numerical dynamic calculations with finite element modeling values of bending moments and longitudinal forces are obtained in the tunnel lining with account three options for location of epicenter of the earthquake. There is given an example of railway tunnel lining by numerical modeling using projecting data and on earthquake of 8 points that on the analysis obtained results are recommended maximum calculated values of internal forces for designing tunnel lining.

Литература

1. Меликулов А.Д., Тоштемиров В.Т. «Современные технологии туннелирования на службе развития международных отношений Узбекистана по древнему Великому шелковому пути». Перспективы развития строительных технологий. ТГТУ, Ташкент, 2014 - стр. 151-154
2. Укшебаев М.Т., Кабашев А.З., Нургалиева М.Р. Основы структурного анализа, технологии и технологии строительства метрополитенов. Издательство Бастау. Алматы, 2010 – 347стр.
3. Спатис А., Гупта Р. Туннелирование в горных породах путем бурения и взрывных работ. Лондон, Тейлор и Фрэнсис Групп, ООО, 2013 - стр. 135
4. Дорман И.Ю. Сейсмостойкость транспортных тоннелей. - М.: Транспорт, 1986 - 176стр.

5. Рашидов Т.Р., Ишанходжаев А.А. Сейсмостойкость неглубоких подземных tunnelных сооружений. Ташкент, Фан, 1994 – 145 стр.

References

1. Melikulov A.D., Toshtemirov W.T. "Modern tunneling technologies at the service of developing international relations of Uzbekistan along the ancient Great Silk Road". Prospects for the development of building technologies. TSTU, Tashkent, 2014 - pp 151-154
2. Ukshebaev M.T., Kabashev A.Z., Nurgalieva M.R. Fundamentals of structural analysis, technology and construction techniques of subways. Bastau Publishing House. Almaty, 2010 - p 347
3. Spathis A., Gupta R. Tunnelling in rock by drilling and blasting. London, Taylor and Francis Group, LLC, 2013 - p 135
4. Dorman I.Y. Earthquake resistance of transport tunnels. – М : Transport, 1986 - p 176
5. Rashidov T. R., Ishanhodjaev A. A. Seismic resistance of shallow underground tunnel structures. Tashkent, Fan, 1994 - p 145

Сведения об авторах / Information about the authors

Миралимов М.Х. – кандидат технических наук, доцент, кафедры дорожного строительства Ташкентского института проектирования, строительства и эксплуатации автомобильных дорог, Ташкент, e-mail: mirzakhid_miralimov@yahoo.com

Нормуродов Ш.У. – ассистент кафедре мосты и тоннели, Ташкентский институт инженеров железнодорожного транспорта, e-mail: normurodov92@inbox.ru

M.X. Miralimov - PhD, associate professor road construction department of Tashkent Institute of design, Construction and Maintenance of Automotive Roads, e-mail: mirzakhid_miralimov@yahoo.com

Sh.U. Normurodov - assistant department of bridges and tunnels, Tashkent Institute of Railway Engineering, e-mail: normurodov92@inbox.ru